Reconnaissance of Damage Due to Hurricanes Katrina and Rita

Physical Security & Systems Interagency Working Group
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Background

- Hurricanes Katrina and Rita caused extensive loss to physical structures (major buildings, infrastructure, residential structures) over a large geographic area

- Hurricane Katrina
  - Number of deaths: ~1300
  - Insured loss estimates: $40-60 billion

- Hurricane Rita
  - Number of deaths: 119
  - Insured loss estimates: ~$4.7 billion

- Damage to structures resulted from:
  - Extreme winds and wind borne debris
  - Storm surge and surge-borne debris
  - Flooding

The Economic Context

- Total economic losses due to Hurricane Katrina expected to be at least $125 billion, including:
  - Tourism losses
  - Costs of repairs to and rebuilding of homes, businesses, roads, bridges, and other infrastructure
  - Lost income of people whose place of employment has closed
- Federal investment of ranging $200K to $400K for each of roughly 500,000 displaced families.
- Hurricane Katrina was the deadliest hurricane to strike the United States since 1928.
- Seven of the 10 most expensive hurricanes in U.S. history occurred in the 14 months from August 2004 to October 2005.
- Hurricane Katrina appears to have destroyed 10 times as many homes as Hurricane Andrew in 1992 or the 4 storms to hit Florida and the Southeast in 2004.
- Hurricane Katrina caused $44 billion in flood and storm surge damage, most of it uninsured, 88% in Louisiana.

NIST Pre-Reconnaissance Deployments

- NIST roofing materials expert deployed with Roofing Industry Committee on Weathering Issues (RICOWI) Sept. 6-10, 2005.
  - Deployment focused on area between Bay St. Louis, MS and Pascagoula, MS.
  - Team conducted reconnaissance of roofing damage to essential facilities, schools, hotels, and residences.

- Four NIST structural engineers deployed with the FEMA Mitigation Assessment Team (MAT) Sept. 26-Oct. 1, 2005.
  - NIST staff operated independently but in cooperation with FEMA MAT.
  - Deployment focused on Mississippi Gulf Coast.
  - Team coordinated with US Army Corps of Engineers to visit levee breaches in New Orleans.

Scope of NIST Reconnaissance

- NIST contracted with the Applied Technology Council (ATC) to assemble a team of experts to augment NIST expertise
- A total of 26 experts were assembled and organized into three teams to conduct field reconnaissance in:
  - Mississippi Gulf Coast (Hurricane Katrina) – Oct. 17-21, 2005
  - New Orleans (Hurricane Katrina) – Oct. 17-21, 2005
  - Southeast Texas (Hurricane Rita) – Oct. 10-14, 2005
- Each of the three teams was further subdivided to focus on major buildings, infrastructure, residential structures

Organizations Participating in NIST Team

- Federal agencies
  - National Institute of Standards and Technology
  - Federal Highway Administration
  - U.S. Army Corps of Engineers
- Private Sector Organizations
  - Applied Technology Council
  - Amtech Roofing Consultants, Inc.
  - Applied Residential Engineering Services
  - ImageCat, Inc.
  - International Code Council, Inc.
  - Scawthorn Porter Associates, LLC
  - Shiner Moseley and Associates, Inc.
  - Smith & Huston, Inc.
- Academic and Research Institutions
  - National Research Council, Canada
  - Texas Tech University
  - University at Buffalo, Multidisciplinary Center for Earthquake Engineering Research
  - University of Puerto Rico

Objectives

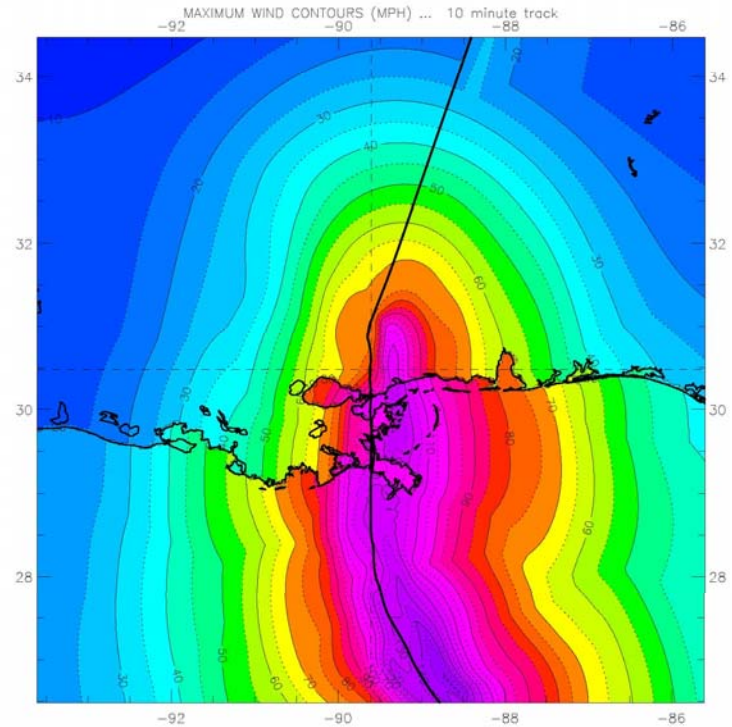
- Collect and analyze:
  - Perishable field data (e.g., first-hand observations, photographic data) on performance of physical structures.
  - Environmental data on wind speed, storm surge, and flooding, and relate environmental data to observed structural damage.
- Review and analyze relevant data collected by other sources (e.g., government agencies, academic and research institutions, industry groups).
- Document field observations, environmental conditions, and data gathered from other sources, and make recommendations for:
  - Repair and reconstruction in the devastated regions.
  - Improving building codes, standards, and practices.
  - Further study of structures or classes of structures that warrant detailed performance assessments.

Coordination with Other Teams

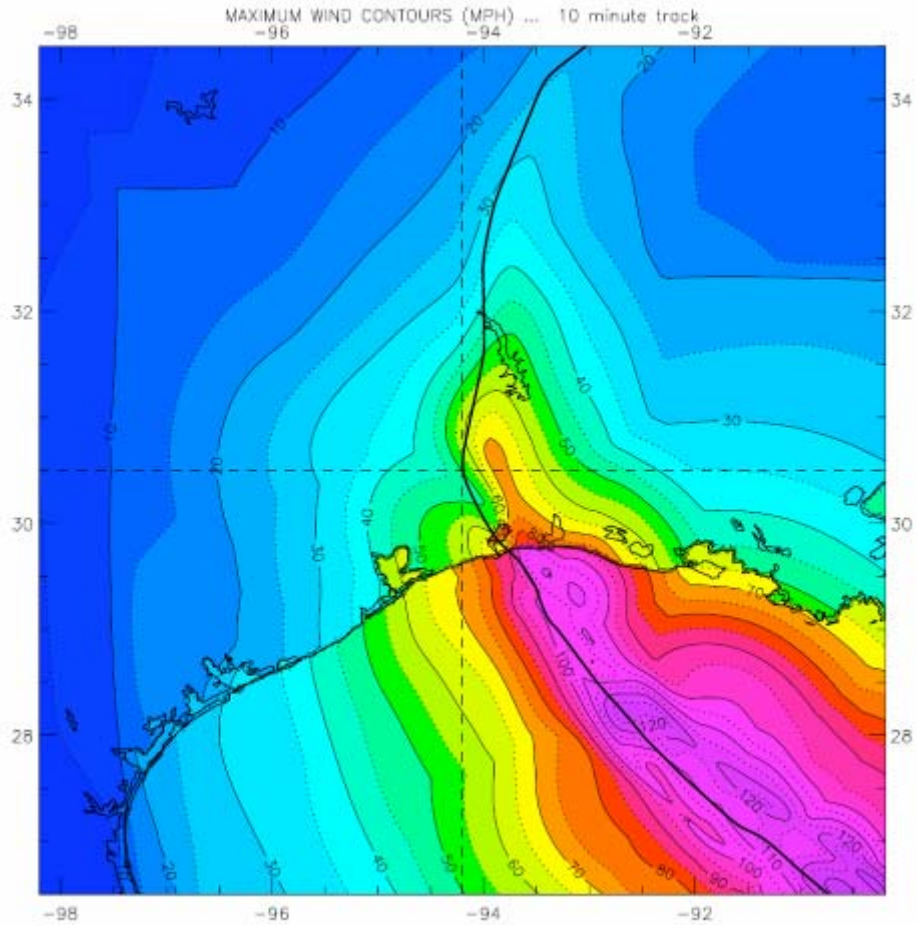
- FEMA Mitigation Assessment Team
  - Damage reconnaissance with focus on mitigation of risks in new or replacement buildings in hurricane-affected areas
  - NIST coordinated pre-reconnaissance with FEMA MAT
- U.S. Army Corps of Engineers
  - Focus on performance of flood control system in New Orleans
  - USACE staff participating on NIST reconnaissance and providing access to data on flood protection system
- Federal Highway Administration
  - Focus on reconnaissance of highway structures
  - Two FHWA staff participating on NIST reconnaissance
- National Science Foundation
  - Two NSF-funded researchers participating on NIST reconnaissance
  - Data from NSF-funded reconnaissance reviewed as part of NIST effort

Environmental Conditions – Wind Speed Data

Katrina



Rita



- **Wind speeds in affected areas were at or below design wind speeds.**
- **Wind speeds diminish rapidly as hurricane passes over land.**

3-s gust speeds are 20 to 25 percent greater than the 1 min averages shown

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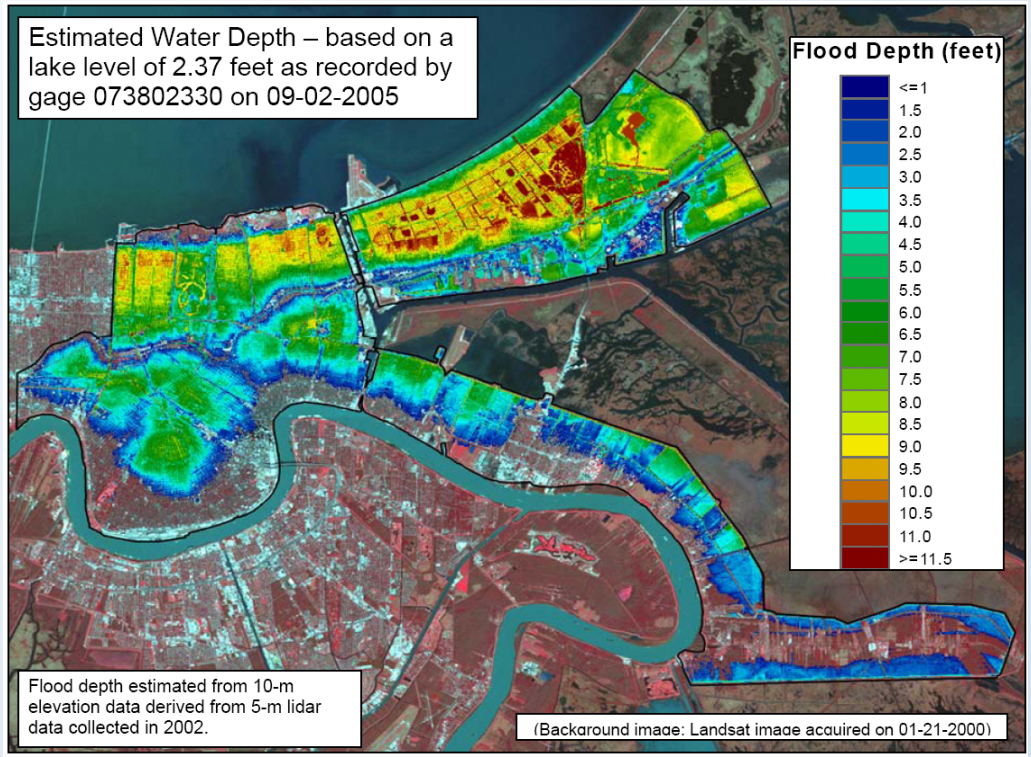
Storm Surge

- Hurricane Katrina
  - 24’- 26’ above Mean Sea Level at east end of Biloxi, MS
  - 30’- 35’ in Pass Christian-Bay St Louis-Waveland, MS
  - 13’ at Mobile, AL
  - Exceeded Hurricane Camille (1969) – up to 12’ higher
- Hurricane Rita
  - Approximately 6’ storm surge measured in Sabine Pass, TX
  - 15’ storm surge in Holly Beach, LA
  - Cameron, LA devastated by storm surge

New Orleans Flooding

- Major levee breaches in 3 canals
- 80 sq mi, 250,000 acre-feet of water
- 100,000 homes, much of downtown flooded
- Geotechnical movement implicated
- Peak flood depth ~2 ft higher than shown on 2 Sep map
- Many major buildings have basements w/critical equipment, etc.
- Humidity, standing water, and no air conditioning aggravated mold damage

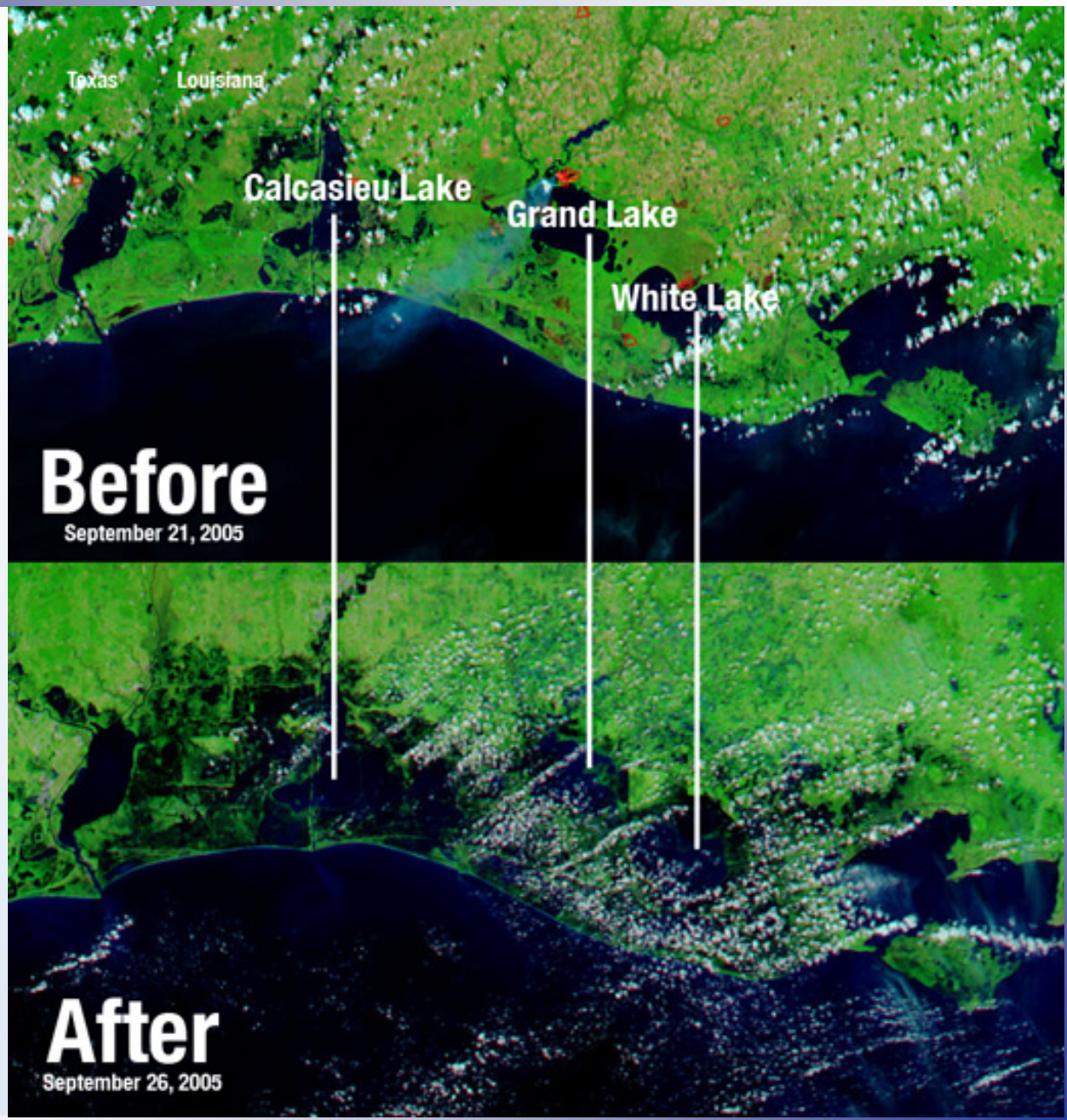


Credit: USGS

Flooding from Hurricane Rita

Landfall:

- September 24
- ~15ft storm surge



http://www.nasa.gov/vision/earth/lookingatearth/h2005_rita.html

High-Velocity Water Due to Levee Breach

17th St Canal Outfall Canal

- Sliding failure of floodwall
- Failure is believed to be due to loss of soil strength resulting from saturation (seepage under sheetpile).
- Overtopping was not believed to occur at this location.

Porter for MCEER

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London Ave Canal Levee Breach

- **Lateral displacement of floodwall due to loss of soil strength on protected side.**
- **Saturation of soil due to seepage beneath sheetpile.**
- **Overtopping not believed to have occurred at this location.**

Scour Behind Levee at Entergy Michaud Power Plant

- Evidence of overtopping at this location.
- Scour on protected side of levee due to overtopping.
- Floodwall remained in place.

Inner Harbor Navigation Canal (Lower Ninth Ward)

- **Overturning failure of floodwall due to overtopping and scour on protected side of levee.**

Window Breakage from Windborne Debris

- **Aggregate surface roofs on adjacent buildings were sources of wind borne debris.**

Building Envelope Failures Due to Wind

- Metal roof and wall cladding
- Brick veneer

Transmission Towers

- ~150 towers, steel poles lost
- Many cascade failures
- Failures caused by wind

138kV line over I-10

230kV line over Highway 73

Distribution Poles

~600,000 poles lost due to wind

Communication Towers/Failures Due to Wind

Cell tower failure, Route 82, coastal LA

Sabine Pass tower failure

Orange cell tower failure

Oil Refineries & Chemical Plants

Cladding damage to towers and tanks due to wind.

Flare tower failure, Orange

URM Wall Collapse in Area Exposed to Water Pressure

Venetian Isles fire station

Reinforced Masonry Wall Damage Due to Water Velocity

Grouted, reinforced masonry wall 20 ft from seawall.
Short lap splice observed at fracture, consequent frame collapse

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Storm Surge Damage on SW Louisiana Coast

Damaged school recreational facility, Cameron

Hibernia Bank building, Cameron

Damaged strip mall, Creole

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Storm Surge Damage, Holly Beach, LA

After Rita

Before Rita

By Arthur Belata / courtesy USACE

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Casino Barge Aground in Biloxi Due to Storm Surge

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U.S. Highway 90 Bridge at Biloxi

- **Failure due to storm surge.**

Major Findings (1)

- Storm surge was the dominant cause of damage in coastal areas and in New Orleans.
  - Storm surge heights exceeded historical records in general.
  - Levee breaches in New Orleans – different failure modes depending on location.
  - Significant damage to residential structures in coastal areas and in New Orleans.
  - Failure of bridges in coastal areas due to uplift and lateral forces displacing bridge decks.
  - Flood damage to backup generators and building equipment located at or below grade.
  - Storm surge not currently considered as a design load.

Major Findings (2)

- Wind and wind-borne debris was the dominant cause of damage away from immediate coastal areas.
  - Significant damage to power distribution system; communications systems.
  - Major buildings suffered damage to glazing due to wind borne debris.
  - Wind driven rain through walls and windows and water ingress through roof vents and wind-damaged roofing systems caused significant damage to major buildings.

Major Findings (3)

- Limitations of Saffir-Simpson Hurricane Intensity Scale
  - Saffir-Simpson scale used in forecasting and evacuation decision making.
  - Hurricane intensity based on measured wind speed; storm surge not considered .
  - Hurricane Katrina was a Category 3 storm at landfall (it had been a Category 5 storm until 18 hours before landfall), but had storm heights consistent with Category 5 storm.
  - Storm surge dissipates much more slowly than wind speed; not accounted for in hurricane intensity scale.

Issues – Major Buildings

- Rooftop construction – aggregate surfaces, screen walls and other materials – source of wind-borne debris.
- Building envelope construction – rain water ingress, wind-borne debris.
- Location of equipment at critical facilities – flooding.
- Mooring requirements for floating casinos – run aground or sink-in-place.
- Masonry building construction – storm surge damage to URM and reinforced masonry, anchoring.
- Metal building construction – failure of roofing and cladding.
- Pre-cast, pre-stressed parking garage systems – failure of first-level due to surge-induced lateral and uplift forces.

Issues - Infrastructure

- Performance of flood control structures (e.g., levees, floodwalls) – protection against overtopping (floodwall), scour (armor), seepage (sheet pile penetration).
- Connection of bridge deck sections to piles – surge-induced uplift and lateral forces.
- Transmission and communication towers – wind-induced failures.
- Location of major electrical generating, transmission and distribution equipment in below-grade facilities in low-lying coastal areas – flooding.
- Anchoring systems for cargo handling cranes in port facilities – failures due to wind (New Orleans) and storm surge (Gulfport).

Issues – Residential Structures

- Lack of building codes in all areas, especially where design wind speeds exceed 100 mph – adoption of national model building codes.
- Building anchorage – displacement from foundation
- Roofing shingles – type (architectural versus three-tab shingles), installation, and wind resistance.
- Performance of metal roofing systems – flashing, attachment, laminar strength of insulation, adhesion between membrane and insulation, old versus new.
- Performance of porous and non-porous cladding systems – wood, brick or masonry versus vinyl or aluminum – rain ingress.
- Undamaged temporary construction – portable classrooms.

Process for Recommendations

- Recommendations will be specific and actionable.
- The recommendations will identify the specific codes and standards affected.
- The recommendations will identify specific agencies with the responsibility for follow through on their implementation.
- NIST is currently considering 26 recommendations as follows:
  - Immediate impact on practice for rebuilding (6)
  - Standards, codes, and practices (9)
  - Further study and research and development (11)

Next Steps

- Complete draft of report received from reconnaissance team on Feb. 27, 2006.
- Draft report currently in review and clearance process.
- Final report planned for release in April 2006.